

STATUS OF THE SUPERCONDUCTING CH-STRUCTURE

H. Podlech, H. Deitinghoff, H. Klein, H. Liebermann, U. Ratzinger, A. Sauer, R. Tiede
 Institut für Angewandte Physik, Frankfurt am Main, Germany

Abstract

The Crossbar-H- or CH-structure is new a multicell drift tube cavity operated in the $TE_{21(0)}$ -mode. It is well suited for protons and ions in the low and medium energy range from 5 AMeV to 150 AMeV [1]. Due to its mechanical rigidity room temperature as well as superconducting operation is possible. A superconducting 352 MHz CH-cavity has been designed and is presently being under fabrication. This CH-prototype cavity will be ready for first cryo tests in 2004. A cryogenic laboratory has been equipped in Frankfurt and has been taken recently into operation.

INTRODUCTION

In the past, different H-mode cavities (IH- and 4-vane RFQ, IH-DTL) have been developed for proton and ion acceleration [1]. All present H-mode structures can be operated only at room temperature. Low duty cycle room temperature CH-structures are presently being under development at the IAP Frankfurt for a dedicated 70 MeV proton injector at GSI, Germany. But the CH-structure can be used also for superconducting operation because of its mechanical properties.

For many future applications superconducting linear accelerators are considered [2][3]. This is especially valid for high duty cycle or cw operated linacs. Together with the use of the KONUS beam dynamics [1] the superconducting CH-structure is an attractive multi cell drift tube cavity especially for machines with a fixed velocity profile like proton drivers. In these cases the CH-structure could be a better choice than Half Wave Resonators (HWR) or Spoke cavities because of the higher real estate gradient at low energies. Examples for possible applications of the superconducting CH-structure are the XADS-Project (352 MHz, protons) [3], the IFMIF project (175 MHz, deuterons) [4] or a cw operated heavy ion linac for the production of superheavy elements [5].

CAVITY PARAMETER

A 352 MHz CH-cavity with 19 cells and a β of 0.1 has been designed and optimized using Microwave Studio [6][7]. The length of the cavity is 105 cm and the diameter 28 cm. The ratio between the peak magnetic field and the acceleration gradient is 7.3 mT/(MV/m) which is a very low value for structures operating in this velocity range. On the other side, the ratio E_p/E_a is 6.59. This means that this prototype will be limited most likely by field emission. But the design gradient of $E_a=3.2$ MV/m leads to an electric

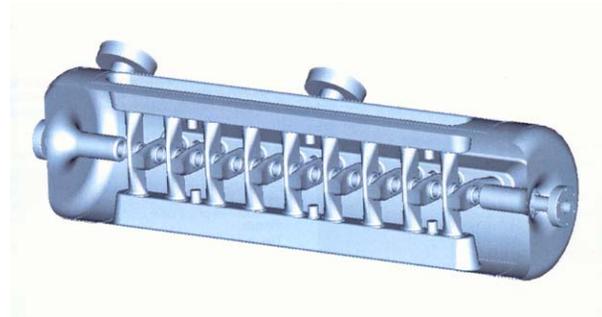


Figure 1: Three dimensional view of the superconducting CH-prototype cavity

peak field of $E_p=21$ MV/m which is still a moderate value. Figure 1 shows a three dimensional view of the superconducting CH-prototype cavity and table 1 summarizes the prototype parameter.

Table 1: Parameters of the superconducting CH-cavity prototype

f [MHz]	352
β	0.1
length [cm]	104.8
diameter [cm]	28
number of gaps	19
R_a/Q_0 [$k\Omega$]	3.22
G [Ω]	56
E_p/E_a	6.59
B_p/E_a [mT/MV/m]	7.29
$E_p @ E_a=3.2$ MV/m [MV/m]	21
$B_p @ E_a=3.2$ MV/m [mT]	23.3
W [mJ/(MV/m) ²]	155
W @ $E_a=3.2$ MV/m [J]	1.58
Q_0 (BCS, 4.2K)	$1.5 \cdot 10^9$
Q_0 ($R_s=150$ n Ω)	$3.7 \cdot 10^8$
P @ $E_a=3.2$ MV/m [W]	9.5
material	bulk niobium
RRR	250
sheet thickness [mm]	2-3

THE CH-PROTOTYPE CAVITY

After a study had showed the feasibility of the production of a superconducting CH-structure the fabrication of the prototype has been started at the company ACCEL



Figure 2: End-caps with drift tubes and girders made from bulk niobium.

(Bergisch-Gladbach, Germany). Due to the complex geometry many fabrication procedures had to be developed. Every production step is first made with copper sheets of the same thickness between 2 and 3 mm. After each successful step with copper the fabrication of the bulk niobium sheets are performed. Presently almost all parts of the CH-prototype cavity are produced with high RRR niobium. Figure 2 and 3 show some of the niobium parts like end caps, girder and stems with drift tubes. Figure 4 shows the CH-cavity in copper prepared for the final electron beam welding. The cavity is expected to be delivered during summer 2004. Before the tests it will be prepared with Buffered Chemical Polishing (BCP) und High Pressure Rinsing (HPR).



Figure 3: Preparation of stems and drift tubes for electron beam welding.

THE CRYOGENIC LABORATORY

To test the superconducting CH-cavity a cryogenic laboratory has been established at the IAP in Frankfurt. It has been equipped with a vertical cryostat, a magnetic shielding (shielding factor 30), two 250 l transport dewars, a class 100 laminar flow box and a helium recovery system. In June 2004 the cryogenic laboratory has been taken into



Figure 4: Due to the complicated fabrication process every step has been performed in copper first.

operation. The test of a 176 MHz, $\beta=0.1$ Half Wave Resonator has started. The control system which has been developed at the IAP has demonstrated the functionality and the cavity could be phase-locked. The average static losses of the cryostat are only 1 W. Figure 5 shows the cryogenic laboratory in Frankfurt with the cryostat (front) and the rf equipment with the control system (background).

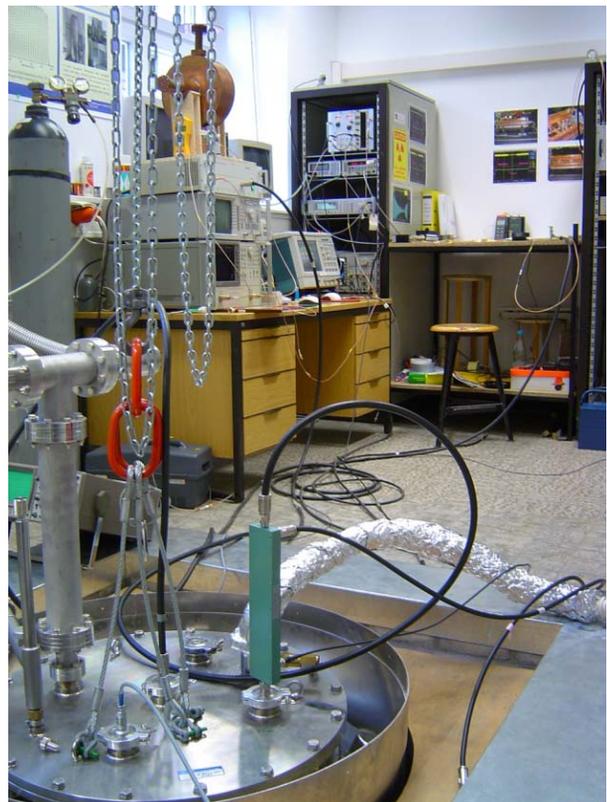


Figure 5: The new cryogenic laboratory in Frankfurt during a first cold test.

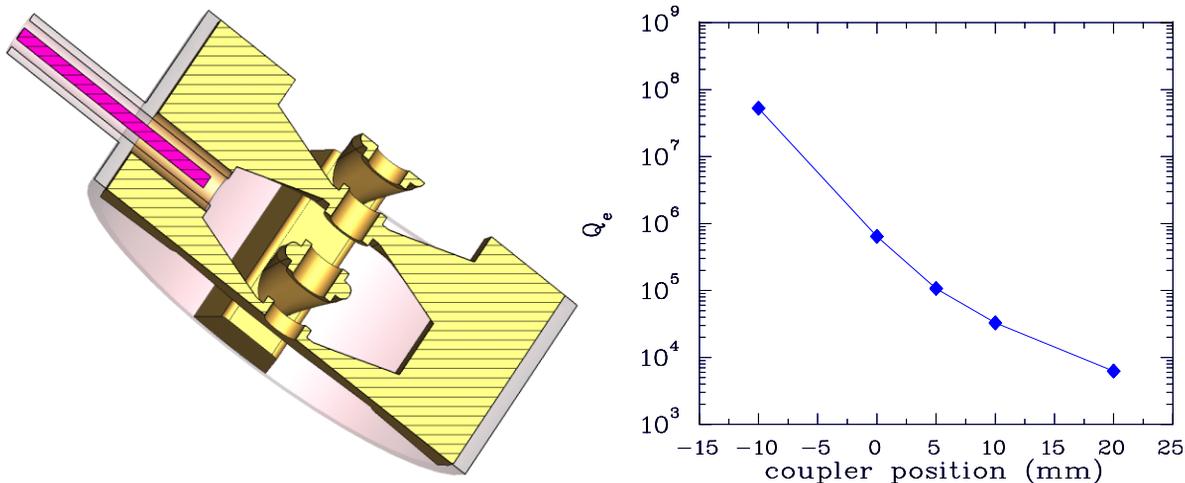


Figure 6: For the first cold tests of the CH-structure capacitive coupling through the girder is foreseen. The right plot shows the simulated external Q-value of a 3-cell CH-cavity as function of the coupler position.

OUTLOOK

The first tests of the CH-prototype will be performed with a broadband 50 W cw amplifier, but a cw amplifier with P=2 kW has been already ordered. It is planned to couple electrically to the CH-cavity with a small antenna which is fed through the girder. Figure 6 shows a plot of the position of the coupler and the simulated external Q-value as position of the coupler. For the simulations Microwave Studio has been used. The external Q-value can be calculated by

$$Q_{ext} = \frac{2fW}{cr_0^2 \ln\left(\frac{r_2}{r_1}\right)} \left(\frac{1}{\epsilon_0 |E_0|^2} + \frac{\mu_0}{|B_0|^2} \right).$$

Recently the development of a mechanical tuner for the superconducting CH-structure has started. The tuning will be done by squeezing and stretching the end-caps. Preliminary simulations showed a tuning sensitivity of 190 kHz/mm which is comparable to elliptical cavities. Additionally, a mechanical analysis regarding microphonics and material stress using the program package ANSYS multiphysics has started [8].

ACKNOWLEDGEMENT

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" program (CARE, contract number RII3-CT-2003-506395). This work has also been supported by GSI and BMBF contr. No. 06F134I.

REFERENCES

[1] U. Ratzinger, Habilitationsschrift, Universität Frankfurt, 1998
 [2] C. Compton, T. Grimm, W. Hartung, H. Podlech, R.C. York, G. Ciovati, P. Kneisel, D. Barni, C. Pagani, P. Pierini, Niobium Cavity Development for the High Energy Linac of the

Rare Isotope Accelerator, Proc. of the PAC2001, Chicago, IL, USA

[3] Requirements for the XADS Accelerator & Technical Answers, DAPNIA-02.302, September 2002, France
 [4] H. Liebermann, H. Podlech, U.Ratzinger, A.Sauer, Design of a End-To-End-Simulations of a Superconducting Deuteron CH-DTL for IFMIF, Proc. of the PAC2003, Portland, OR, USA
 [5] R. Eichhorn, RF Structures for Linear Acceleration of Radioactive Beams, Proc. of the PAC2001, Chicago, IL, USA
 [6] H. Liebermann, H. Podlech, U.Ratzinger, A.Sauer, Design of a Superconducting CH-Cavity for Low- and Medium Beta Ion and Proton Acceleration, Proc. of the PAC2003, Portland, OR, USA
 [7] <http://www.cst.de>
 [8] <http://www.ansys.com>